WEATHER-FORECASTING MEETING OF THE NATIONAL ELECTRIC LIGHT ASSOCIATION IN SAN FRANCISCO.[1]

By E. A. Beals, Meteorologist.

[Weather Bureau, San Francisco, Calif., Mar. 19, 1921.]

On February 18, 1921, the National Technical Section of the National Electric Light Association, under the auspices of its Pacific Coast Geographic Division, held a meeting at San Francisco, devoted to discussions of weather forecasting. The chairman of the meeting, Mr. H. A. Barre, in his opening address said, in part:

> As we stand now every additional ton of agricultural products produced in California, and every additional ton of industrial output produced must come from the use of electric power, and the development of that power, in some measure, conflicts with the use of streams for irrigation.

Mr. Barre further explained that the feeling that engineers in general were not sufficiently acquainted with meteorological and climatological relations to water supply was the main thing that prompted this convention to consider forecasting problems.

The first paper presented was by Dr. W. E. Ritter, director of the Scripps Biological Institute. He stated that he was a member of a committee that is undertaking an international survey of the Pacific Ocean, embracing the subjects of oceanography, meteorology, and hydrology. Dr. Ritter expressed his conviction that so far as California, Arizona, and New Mexico are concerned the water supply is the limiting factor in determining the size of the population that can be supported in those States. Hence every energy should be directed toward a thorough investigation of the water supply, which of course is ultimately a matter of precipitation.

The next speaker was Mr. E. A. Beals, district forecaster of the Weather Bureau at San Francisco, who addressed the meeting on "Long-Range Weather Forecasting." This paper lays particular stress on the possibilities of making long-range predictions of rainfall for the Pacific coast. Attention is called to the necessity of more extended study of the behavior of the Aleutian center of action, as off-shoots coming from it apparently cause the greater part of the rainfall of the Pacific States. While expressing the opinion that there is no immediate prospect of successfully solving this problem, Mr. Beals feels it may be eventually solved to the extent of answering the practical purposes of engineers and others interested in this problem of weather forecasting.

In conclusion the speaker informed the convention of the great interest of the Chief of the Weather Bureau in the efforts to develop long-range forecasting to a point where it may be of practical use, and of his advice that very long weather records be examined carefully by statistical methods before attempting practical applications.

Father Ricard told of the occurrence during recent years of a LOW or a HIGH on the Pacific coast simultaneously or within a day or two of the time when a sunspot crosses the central meridian in the northern or the southern hemisphere, respectively, of the sun. He urged the improvement of rainfall forecasting by the use of daily observations of the electric state of the atmosphere as well as by further studies of sunspots and oceanography.

Mr. B. M. Varney, of the Department of Geography, University of California, followed with an address on "The Distribution of Precipitation in Washington, Oregon, and California." He reminded the convention that the Weather Bureau some time ago classified the system of low-pressure areas on the Pacific coast into the north Pacific type and the south Pacific type. The LOWS entering from the north Pacific pursue an average path (subject to wide variations) carrying the centers of low pressure over the Puget Sound country, while those of the south Pacific type have an average entrance somewhat north of Point Conception. Mr. Varney points out that the regional distribution of rainfall in California is very largely a matter of the frequency of these two types of pressure activity.

The subject of variation of precipitation with change in altitude is treated quite fully by the author.[2]

"Snowfall with Particular Reference to California," by Mr. A. H. Palmer, of the San Francisco Weather Bureau office, in the absence of Mr. Palmer was read by Chairman Barre. The following paragraphs give the scope of the paper:

> The snow deposits in the mountains of California have recently come to be recognized as one of the most important natural resources of that richly endowed State. Snow is a natural storage reservoir and upon melting forms (1) the only source of supply of irrigation water, without which there could be no extensive agriculture, and (2) a means of developing hydroelectric power, upon which the State's industrial future is largely dependent. When the nation's coal reserves are exhausted and the rapidly diminishing oil supply has been depleted, the potential energy contained in the elevated snow fields of the West will case a westward migration of industry, a movement which has already begun.
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> The heaviest snowfall in North America is found in the higher portions of the Olympic Mountains of Washington, the Cascades of Oregon, and the Sierra Nevada of California. It is not unusual for depths of 50 feet or more to accumulate on the ground at one time. While snow as it falls is ordinarily about 10 per cent water, by volume, that which accumulates on the ground packs and solidifies because of pressure and through alternate thawing and freezing. The great snow deposits found in spring are 30 to 40 per cent water, by volume, and through slow melting in summer form the only water supply, as the summer half-year is practically rainless in California.
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> Because of improved methods of transmission, hydroelectric power is now conducted 200 to 300 miles to market. Nearly all the hydroelectric trunk lines in California run from north to south. Some of the power consumed in the San Francisco industrial region comes from the melting snows of mountains along the California-Oregon boundary.
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> For measuring snowfall the difficult problem is that of securing a proper catch. The most satisfactory instrument devised for this purpose is the Marvin Shielded Rain and Snow Gage, a massive instrument designed by Prof. C. F. Marvin, Chief of the United States Weather Bureau. It is 9 feet in height, and about the mouth of the cylindrical can, which forms the gage proper, there is a double arrangement of wind shields. For determining the density of snow on the ground, the most satisfactory instrument is the snow sampler, first used extensively by Prof. J. E. Church, of the University of Nevada, and subsequently improved and perfected by Mr. B. C. Kadel, of the Weather Bureau. The sampler is a metal tube which is plunged through the snow to the ground, and the snow column thus secured is subsequently weighed by means of a spring balance.
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> In view of the rapidly diminishing coal and oil reserves, it behooves us of the present generation to make a more nearly complete use of the vast energy now going to waste in our unharnessed streams. Future generations will not hold us guiltless if we continue to consume the limited coal and oil supply and allow the limitless energy of mountain streams to go to waste.

The evening session of the convention began promptly at 8 o'clock, and the first paper was entitled, "Scientific Long-Range Weather Forecasting" by Dr. Charles F. Brooks. Owing to his absence this was read by Chairman Barre and received with rapt attention.

Dr. Brooks is quite optimistic regarding the possibilities of making dependable long-range forecasts. He

[1] To be published in full in the proceedings of the National Technical Section, Pacific Coast Geographic Section, National Electric Light Association.

[2] Varney, B. M. Monthly Variations of the Precipitation-Altitude Relations in the Central Sierra Nevada of California. (2 figs.) Mo. Weather Rev., Nov., 1920, 48: 648-650.

takes the ground, however, that "the Weather Bureau can not experiment at public expense upon the public itself" and until a sufficiently sound, scientific basis has been reached the Weather Bureau would not be justified in attempting to make forecasts of this character.

Dr. Brooks said:

The long-range forecast goes beyond the realm of storms already in existence and which by their movement may be likely to affect us some time next week. Its success or failure depends on weather features yet to be born. Long-range forecasting, therefore, has but little in common with day-to-day forecasting, or even with forecasting on Saturday what the general character of the weather during the comng week will be.

He cited methods now in operation in India and Java, based in the former case upon the distribution of pressure affecting the southeast trade winds and their continuation into the summer monsoon winds; and in the latter case upon modifications of three-year periods of local pressure, winds, and rainfall. Besides these examples, Dr. Brooks thinks long-range forecasts are possible, "in view of what we know about the sequence of the weather, the periodicity of solar changes, and the relations between weather in widely separated parts of the earth."

In discussing these points great stress was laid upon the fact that sequences in the weather are not wholly fortuitous. They may come, he thinks, as the result of accumulation of slowly changing forces to a point where the existing balance of weather is overturned. Or they may appear as a result of a marked dimunition in the absorption of solar radiation into the earth's atmosphere over a considerable area, owing to changes in reflection, if not to actual changes in heat arriving from the sun.

Periodicities in weather were mentioned for such short intervals as a week, a fortnight, or 4 weeks, also for longer ones; such as, 8 months, 2 years, about 3 years, 5½ years, 7 years, 11 years, and 33 to 35 years. These, he says, are interesting, for almost without exception there seem to be corresponding solar periods, though in the case of the shorter ones they are uncertain.

Dr. Brooks agrees with Köppen, Walker, Helland-Hansen & Nansen, and others that fluctuations in the weather for some of the periods bear a close relation to solar activity, but he thinks until this relationship is more closely established, it is impracticable to make long range weather forecasts from our present knowledge regarding changes taking place in the amount of heat received by the absorption from the sun. Another drawback to predictions of this character would occur through our not being able to forecast the solar changes, as Dr. Brooks thinks they meet with some immediate response in the mobile atmosphere, though there are others who think they act more slowly by affecting the centers of action, and these in turn the weather at distant points perhaps several weeks or months afterwards.

In his discussion of the occurrence of similar or opposite abnormalities in the weather of widely separated parts of the earth simultaneously or a few months apart, he says it is suggestive of not only the unified response of the atmosphere to any major influence, but also of delayed reactions, dependent perhaps, largely on the slowness of travel of ocean waters.

After describing how the ocean waters are warmed and cooled above their averages for different latitudes by a change in wind direction or an increase in wind velocities, he stated these effects can be traced for many months to far-away regions and it is therefore possible to base seasonal weather forecasts upon ocean surface temperatures.

Dr. Brooks cited a hypothetical case, where a body of unusually warm water coming through the Strait of of Florida would in 8 or 10 months influence the weather off the west coast of Europe, and prior to this affect the weather when passing north and northeast off the east coast of the United States.

While declaring long range forecasting from ocean temperatures would be a complex and laborious practice, he feels that there would be few who would hesitate a moment on this account, as the value if successful would repay many times over the cost of their preparation.

In conclusion, Dr. Brooks emphasized the need of learning more about the changes in the sun and their relation to changes in the weather, and above all the importance of gathering more information about the weather of the world.

He said:

For the vast expanse of the ocean, covering three-fourths of the surface of the globe, we must rely on the few ships, which do not cross all regions, but most of which keep to rather narrow lanes. Just consider these figures: The Weather Bureau receives from the whole North Atlantic but 100 or 200 observations per day, and only half as many from the North Pacific. For all the other oceans the score or two of daily observations is approximately equivalent to an average of one for every 3,000,000 square miles, or an area approximately equal to that of the United States. What would we know about the weather of the United States if there were but one station reporting each day and the same station probably never reporting twice in a year, or perhaps even in 10 years?

The meteorological analogy of southern California, southwest Africa and west Australia and the narrowest of the Atlantic and Indian Oceans, in comparison with the Pacific, might similarly make it worth while to look for indications of California rainfall in the rainfall of those distant regions. Furthermore, with the aid of correlations found for parts of Europe as guides for corresponding investigations in the Pacific, correlations with a delay of a few months may be found to give indications of the seasonal weather to be expected here. But however successful these may be, they could not compare with what could be done with accurate knowledge of the weather and surface temperature conditions of the North Pacific Ocean. That region seems to be the breeding place for weather types of the Pacific coast of the United States, therefore, that is the region which we must study in order to say when there will be a drought and when there will be floods in the Pacific States.

Following Dr. Brooks, an illustrated lecture on, "Indications of Seasonal Variations of Weather in the Growth of Rings of Trees," was given by Dr. A. E. Douglass, director of the Steward Observatory, University of Arizona.

He stated:

This work on tree rings, which I have been interested in for a great many years, is, you understand, a study that is not yet finished, and as it were, I am giving you a sort of report of its present condition.

Dr. Douglass' own synopsis is as follows:

The data here given were obtained in the identification and measurement of more than 100,000 rings in some 400 different trees. The trees included groups of Douglas firs from Oregon, *Sequoia gigantea* from California, yellow pines from Arizona and Colorado, hemlocks from Vermont, and Scotch pines from northern Europe. Many trees have systems of rings that show the influence of climatic conditions. For example, the yellow pines growing near Prescott, Ariz., give a rainfall record with an accuracy of 70 per cent. A slight conservation formula which recognizes different states of activity of the trees raises this correlation to 85 per cent. The giant sequoias show some relationship to the rainfall at Fresno and other points in the great California Valley. It is regretted that full weather records are not being taken in the immediate vicinity of these giant and aged trees.

Many cycles are exhibited by the trees, of which the most pronounced is the sunspot cycle or some of its harmonics. The trees around the Baltic Sea exhibit a pronounced rythm whose maximum occurs at sunspot maximum. The cone-bearing trees in the moist climates of this country, so far as tested, also show the sunspot cycle conspicuously, but with a difference in phase from the European trees. The pine trees of northern Arizona show the half sunspot cycle in a pronounced manner. The variation of these pines from the year 1400 to 1550 and even 1650 is one of the most marked cases of rhythm which I have observed. The double sunspot period of about 22 years is conspicuous in the Arizona pines, and the triple sunspot period shows in them for the last 200 years. Both these multiples of the sunspot cycle are found also in the European trees. Of longer periods one extending a little over 100 years in the Sequoias and in the pines is the most conspicuous.

An instrument called the periodograph has been designed along optical lines for the purpose of analyzing any plotted curve into its component periods. This instrument does not readily give the harmonic constants, but it does give the periods existing in almost any complex mixture. The use of this instrument has confirmed the cycles mentioned above. When applied to the 3,000 years of the growth record of the Sequoias it gives some very interesting facts. First, that this form of analysis promises to be of assistance in outlining meteorological districts of homogeneous character. Second, that the sunspot cycle of a trifle over 11 years was existing 3,000 years ago. Third, that different centuries have probably been characterized by different combinations of climatic cycles. This will very likely assist in solving some archaeological problems, and in fact, the study of growth rings in prehistoric timbers has already given valuable information in regard to primitive construction of buildings.

The chief use of the evidence in trees in the matter of climatic cycles is a verification of the existance of those cycles over long periods, and a chance of studying them to great advantage with the analyzing instruments above referred to.

After a brief discussion of the lecture by Dr. Douglass, the meeting was addressed by Dr. Geo. F. McEwen, of the Scripps Institute, who, after describing the scope of oceanography and the circulation of ocean currents, gave some specific results of work that has been done in the Pacific. He stated:

While conducting a continuous investigation of certain oceanic phenomena at the Scripps Institution pier, near La Jolla, southern California, a relation was indicated between sea temperatures observed during the summer months and the amount of rain falling during the following winter months. This continuous series of observations began in 1916, and up to the present time (October, 1920) indicates that the lower the summer temperature, the higher will be the rainfall in southern California during the following winter.

While it would be surprising if such a simple empirical relation as has been found for so short a time interval should continue to hold thus accurately in the case of as complex a system as the ocean and the atmosphere, it seemed advisable to call attention to the result, owing to the great advantage in using all possible means for obtaining some indication of the coming rainfall.

Dr. McEwen illustrated by means of graphs a correlation he had discovered between the temperature of the ocean and fog near its shore. He showed that between Point Arguello and San Diego the fog was least where the departure of the temperature of the ocean surface was least below normal and greatest where the temperature departure was the most below normal. These differences below normal of ocean temperatures, he thinks, are proportional to the barometric gradient from the center of the permanent North Pacific high-pressure area, and as the meteorological conditions are related to the pressure conditions, and the pressure conditions are reflected in ocean temperatures, there may be a means through the study of the ocean temperatures of getting at some of the meteorological changes, and possibly making predictions.[3]

After a short discussion, a paper entitled, "The Problem of Seasonal Weather Forecasting," by Maj. E. H. Bowie, was read by Mr. Armstrong. Mr. Bowie stated that meteorology has for its goal the making of accurate forecasts of wind, weather, and temperature for long periods in advance. The making of such forecasts has for years received consideration from meteorologists of good repute, as well as from others not wholly scientific in their understanding of the question. The latter, he thought, have been a hindrance rather than a help to those of honest endeavor engaged in solving this difficult problem.

[3] The paper published in *San Diego Farm Bureau Monthly*, Jan.-Feb., 1921, 7:1, 4.

Mr. Bowie, in mentioning the study that has been given the frequently marked deviation from the normal in meteorological elements, cycles, sunspots, and variations in the solar constant, says that all so far have failed to bring forth a working hypothesis capable of leading the way to the making of forecasts of sufficient accuracy to be of value.

As nothing definite has been evolved after so much painstaking study, he thinks the right combination has not yet been found, or else the records studied do not cover a sufficient length of time really to get at the facts in the case. If the records are too short to develop periodicities, or if it should happen there is none, we should not give up, as he thinks long-range forecasts may possibly be made after a better understanding has been obtained regarding the primary circulation of the winds of the earth's atmosphere.

This circulation is subject to marked deviations from the normal, which are brought about by influences that are world-wide in their operation. In illustration, Mr. Bowie says:

We know that abnormally high pressure off the California coast and low or relatively low pressure over Alaska and the Aleutian Islands will give a minimum of rainfall in southern California, and that the seasons of plus deviations from the normal are associated with high pressure over the interior of Alaska, a southward extension of the semipermanent winter LOW over the Aleutian Islands, and at the same time a breaking down of the high pressure off the California coast. The inference is that under the latter condition the lower air strata in the eastern Pacific flows up the west coast of Mexico and, gradually losing temperature and becoming supersaturated, give the wished-for rains, while under the former condition the winds off southern California are from the northwest, and, moving southward and becoming warmer, depart more and more from a state of saturation.

Mr. Bowie is of the opinion that a thorough study of the "tendencies" of the general circulation over the Pacific Ocean and Asia preceding the beginning of the rainy season will lead to important conclusions concerning rainfall in California, and the thing to do is to outline means for procuring the information wanted.

This, he says:

will entail the gathering and compiling of observations from all points within and bordering on, and from vessels sailing on the Pacific Ocean. A by no means small task, but it would be worth while; moreover, this will be a step toward the preparation of daily, seasonal, and yearly charts of the atmospheric conditions of a world-wide nature. Perhaps when such charts become available for study purposes many of the problems confronting meteorology will be possible of solution.

Owing to lack of time, Prof. Henry's paper, on "Long-Range Forecasting," was not read at the meeting, but was submitted and will appear later in the printed proceedings of the convention.

Prof. Henry's paper contains a large amount of historical matter relating to the subject which is interesting, but not of a character to promise hopeful results. He agrees with Maj. Bowie that the most promising avenue of approach to the problem of seasonal weather forecasting is a better understanding of the pressure distribution over the globe. This, he says:

is not a question of the pressure distribution over a single geographic unit, but rather the world-wide distribution must be forecast before we may hope to indicate what type will prevail in the United States, for example.

There is evidence, he says:

that the pressure distribution over the Canadian Northwest, including Alaska and the Pacific, westward from the continent some hundreds of miles, exerts a profound influence upon American weather, particularly that of the western United States. In like manner the pressure over the middle western portion of the middle North Atlantic, in conjunction with the pressure over northwestern Canada, exerts a strong influence upon the weather in the eastern part of the country. Manifestly, then, in any rational scheme of long-range weather forecasting it is necessary to determine in advance what type of pressure distribution will prevail throughout the season.

Differences in pressure on the earth's surface, Prof. Henry said:

are largely dynamic results due to motions of the atmosphere, and likewise the areas of high barometer and low barometer, respectively, may also be largely due to the aforesaid motions, but the ultimate cause of their formation is due to differences in the density of the atmosphere, which in turn are due to differences in temperature and moisture distribution.

Because of the importance of these motions causing changes in the character of the high and low barometric areas over the north Pacific Ocean, Prof. Henry thinks there is need above all else of more well established facts concerning the weather conditions which result from them. These facts are not at hand, and hope of obtaining them rests largely in the rapid multiplication of ship observations throughout the vast expanse of the Pacific Ocean.

Should these be forthcoming, he says:

It may be possible to discover the preliminary symptoms of the changes in position and intensity of the Pacific HIGH, which, if accomplished, will be a forward step toward the goal.

Prof. Henry does not believe that an examination of rainfall records of the past would be worth while, as a comprehensive analysis has already been made of many of them without discovering any periodicities that could be used for forecasting purposes.

He does not think the matter is definitely settled in the negative, but believes we must wait upon civilization and settlement in unrepresented districts for further observations, and when they are obtained additional light will be thrown upon that which is now obscure. Our best efforts in the meanwhile "should be directed toward the enlistment of more and more ship captains in the meteorological service."

SEASONAL FORECASTING OF PRECIPITATION—PACIFIC COAST.[1]

551.509 : 551.578.1 (79)

By ALFRED J. HENRY, Meteorologist.

[Weather Bureau, Washington, Mar. 8, 1921.]

SYNOPSIS.

An examination is made of the observational data of past years bearing upon the subject. This examination shows clearly that the distribution of precipitation in Pacific Coast States is not, as a rule, of the same order of intensity, indeed fairly heavy precipitation in Washington and Oregon may be associated with deficient rainfall in California, and vice versa. The physical grounds for the difference in distribution are next sought. Three classes of seasonal distribution are distinguished, and these in turn are discussed with reference to their probable causes.

The conclusion is reached that a knowledge of the pressure distribution over the northeastern portion of the Pacific Ocean and the Canadian Northwest affords the most hopeful avenue of approach to a rational solution of the problem.

The annual precipitation in Pacific Coast States ranges from a few inches in extreme southeastern California to more than 100 inches in the foothills of western Oregon. There is thus a very pronounced increase in precipitation with increase in latitude, which is more noticeable in California than in either Washington or Oregon. The greatest contrasts, however, are those between the precipitation of the lowlands and that of the mountain masses which parallel the great interior valleys. This contrast is greater on the leeward than the windward side of the higher mountains.

Perhaps nowhere in the North American continent is the seasonal character of the annual precipitation so conspicuous as in California, where more than 50 per cent of the annual precipitation occurs in the three winter months of December to February, while the months of June to September are practically rainless, except upon the higher mountain summits.

Statistics available.—The most readily available statistics for the region under consideration are those found in Table 1 of the MONTHLY WEATHER REVIEW. This table, in very nearly its present form, was begun in the last half of 1884; at that time it bore the heading "Table of Miscellaneous Meteorological Data, Signal Service Observations" in the beginning the monthly departures were not known. It is fairly complete in the last respect after 1892, although strictly speaking the homogeneity of the record is not as great as could be desired. The exigencies of the service at times made it necessary to discontinue an observing station or to remove it a short distance from its original location. Most of the changes in the observing stations that took place during the 29 years considered were of that order. The original stations in the north Pacific coast region were: Fort Canby, Neah Bay, Olympia, Port Angeles, Tatoosh Island, Wash., and Astoria, Oreg. For the middle Pacific coast region in 1892, the following named stations were used: Eureka, Point Reyes, and San Francisco, all on the coast, and Red Bluff and Sacramento in the interior. The south Pacific coast region was represented by the stations at San Diego, and Los Angeles one of which is on the coast, the other but a short distance therefrom. The interior of southern California was represented by the station at Fresno. The original table above referred to gives the mean precipitation for the month for each of the three districts and the departure from the normal the latter being computed from those records of 10 to 20 years in length. I have combined the departures from the normal of the three winter months, into a single expression which represents the abnormality of the winter as a whole beginning with December, 1891, and continuing through until February, 1920; thus in Table 1, which immediately follows, the figures 2.5 inches, 2.9 inches, 2.9 inches in the columns headed "North," "Middle," and "South," respectively, indicate that precipitation for the winter 1891–92 was deficient by these amounts in the respective districts. The full-faced figures indicate positive departures, while negative departures are printed in the ordinary type. These figures are obtained by adding algebraically the departures of the three winter months; they represent, therefore, the total or accumulated departure and not the mean departure.

TABLE 1.—*Winter precipitation departures—Pacific Coast States.*

[Accumulated departures in inches and tenths.]

Years.	North coast.	Middle coast.	South coast.	Years.	North coast.	Middle coast.	South coast.
1891–92	2.5	2.9	2.9	1906–7	3.8	2.7	2.9
1892–93	4.0	1.7	1.5	1907–8	0.5	1.3	0.9
1893–94	3.0	1.8	2.7	1908–9	1.6	8.6	5.6
1894–95	7.1	5.4	3.2	1909–10	3.2	3.2	2.0
1895–96	9.5	3.3	4.2	1910–11	5.2	2.3	3.6
1896–97	2.4	0.8	1.5	1911–12	2.8	6.0	4.5
1897–98	3.8	6.4	5.4	1912–13	3.4	6.9	1.5
1898–99	2.6	6.2	4.7	1913–14	0.5	5.1	6.6
1899–1900	2.3	3.6	5.2	1914–15	8.6	7.4	6.6
1900–1901	2.0	0.2	0.6	1915–16	3.5	6.0	8.1
1901–2	1.2	1.3	3.2	1916–17	6.3	1.8	2.7
1902–3	1.9	3.0	1.1	1917–18	5.7	3.9	1.0
1903–4	2.0	2.5	4.4	1918–19	1.4	0.5	1.6
1904–5	4.8	4.1	0.5	1919–20	8.5	8.6	2.6
1905–6	3.8	2.9	2.0				

Negative departures in ordinary type, positive in full-faced type.

[1] This is a discussion of the specific problem of long range forecasting for the Pacific coast. It is not identical with the paper by the same author mentioned in the preceding article.—*A. J. H.*